DINOFLAGELLATE CYSTS AND ACRITARCHS FROM UPPER BAJOCIAN TO MIDDLE BATHONIAN STRATA OF CENTRAL AND SOUTHERN ENGLAND

by J. P. G. FENTON, R. NEVES, *and* K. M. PIEL

ABSTRACT. Ten samples for palynological analysis were collected from three localities, Hook Norton, Bruton, and Burton Bradstock, in central and southern England. All samples contained abundant Middle Jurassic microplankton and the following taxa are described as new: *Dichadogonyaulax adelos* sp. nov.; *Gongylodinium erymnoteichos* gen. et sp. nov.; *G. hocneratum* gen. et sp. nov.; *Kylindrocysta spinosa* gen. et sp. nov.; *Tenua asymmetra* sp. nov. *Caddasphaera halosa* gen. nov. comb. nov. and *Leptodinium pectinigerum* are proposed as new combinations. The stratigraphical significance of the assemblages is discussed.

As part of a wider investigation into the distribution of palynomorphs in the Middle Jurassic rocks of England, ten samples of Upper Bajocian to Middle Bathonian age were collected from three well-known localities that are dated by ammonites—Hook Norton, Oxfordshire; Bruton, Somerset; and Burton Bradstock, Dorset (text-fig. 1). The palynological assemblages recovered contain abundant, well-preserved, and diverse dinoflagellate cysts, acritarchs, and miospores. This paper is concerned with the two former categories, which include new taxa and are of stratigraphical value.

Slides containing the illustrated types and assemblage strew mounts are retained in the collection of the Micropalaeontology Laboratory, Department of Geology, University of Sheffield. All specimen locations on the slides are given by England Finder co-ordinates.

STRATIGRAPHICAL LOCATION OF SAMPLES

1. *Burton Bradstock, Dorset.* The oldest sample (BB5) was collected from the *Truellei* Bed of the Burton Limestone, which is exposed in the road cutting leading to the cliff top at Burton Bradstock (Grid Reference SY487889). A sample of blue/grey oolitic limestone was collected 0·3 m above the base of the bed, which is here 0·5 m thick, and has been attributed to the *S. truellei* Subzone of the *P. parkinsoni* Zone (Upper Bajocian) by Richardson (1928, p. 62) and Parsons (1974).

2. *Hook Norton, Oxfordshire.* The best exposure at Hook Norton is on the eastern side of the disused railway cutting, south of the tunnel entrance (SP367317, Duckpool Farm cutting of Walford 1883; see text-fig. 2). Samples HNRC 1–6 were collected from this section where the Upper Bajocian–Lower Bathonian rests unconformably upon Upper Liassic shales and clays (*H. bifrons* Zone; Howarth 1978, p. 247). Lithological correlation with the section documented from the north cutting by Richardson (1911) is fairly straightforward (text-fig. 1, loc. 2). About 2·1 m of Aalenian strata (belonging to the *L. opalinum* Zone) which are present in the north cutting are absent, as noted by Walford (1883, p. 243) and Horton (1977, fig. 2). These strata have been attributed to the *Scissum* Beds by Richardson (1911) and the Northampton Sand by Horton (1977), these terms applying to laterally equivalent strata.

The Upper Bajocian Hook Norton Conglomerate Beds (Beds 22–24 of Richardson 1911) are expanded in thickness from 0·5 m in the north cutting to 0·9 m in the south cutting, where they rest directly upon the Lias. Samples HNRC 1–3 are from these beds, a series of intercalated variegated oolitic muds and clays, bioclastic oolitic or even pisolitic microsparitic limestones with occasional lenses of homeolithic pebbly limestones. Both Richardson (1911) and Horton (1977) have correlated them lithologically with the *Clypeus* Grit, which has been assigned to the *P. bomfordi* Subzone of the *P. parkinsoni* Zone (Parsons 1976).

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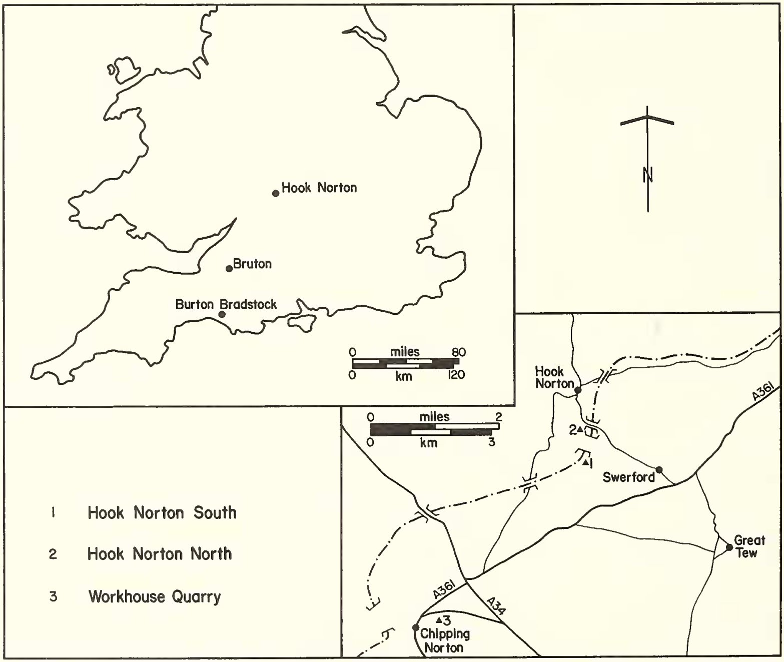
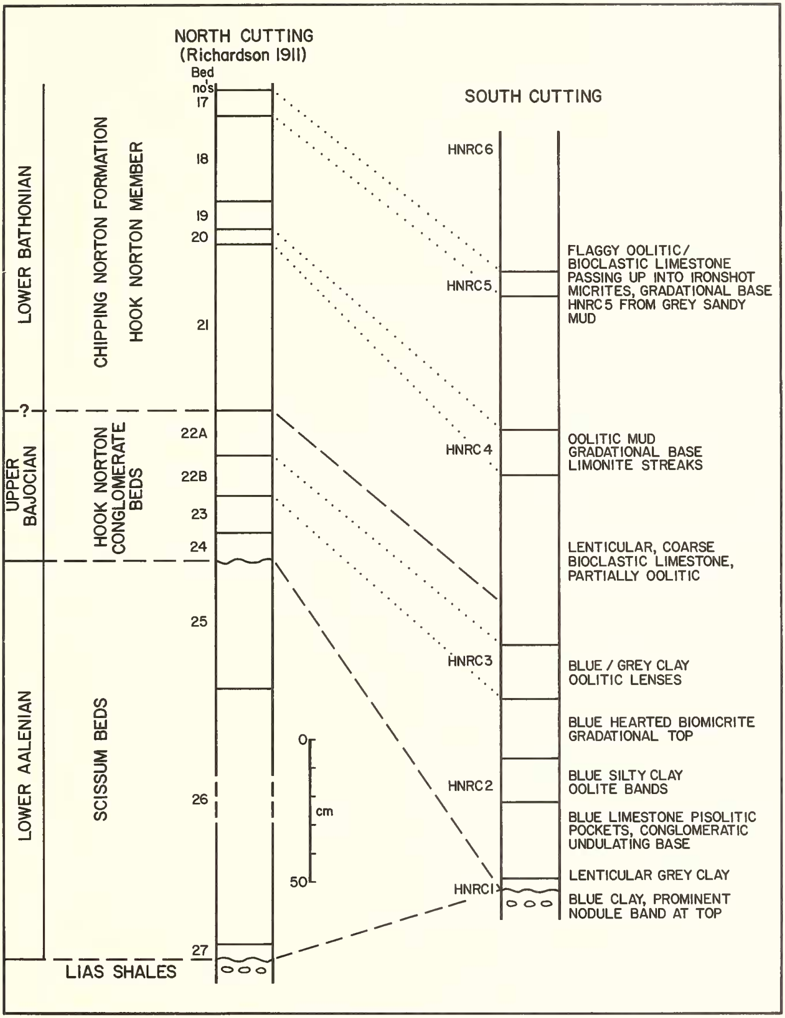
Samples HNRC 4–6 are from within the Hook Norton Member, a sequence of oolitic and bioclastic sandy limestones, oolitic sandy muds, and calcareous quartz sands, all rich in lignite. This Member forms the basal part of the Chipping Norton Formation, and the Bajocian–Bathonian boundary is thought to occur near its base (Torrens 1968, p. 228). The upper part of the Member is assigned to the *P. convergens* Subzone of the *Z. zigzag* Zone (Lower Bathonian) (Torrens 1968). At Workhouse Quarry, Chipping Norton (SP319276), approximately 3·5 km to the south-west (text-fig. 1, loc. 3) the boundary is thought to occur about 1 m below the *Trigonia signata* Bed (Parsons pers. comm. 1978). Richardson (1911) correlated the latter with Bed 12 ('The Old Man') of his account of the north cutting at Hook Norton. Detailed correlation of the section studied with that above Richardson's Bed 17 in the north cutting must remain tentative. However, if the Bajocian–Bathonian boundary occurs at approximately the same horizon below the *T. signata* Bed as supposed at Chipping Norton, it will be near the horizon of Beds 18 and 19 of Richardson (1911). Horton (1977, p. 151), however, states that no evidence has been found during the recent geological investigation of the Chipping Norton area (Geological Survey Sheet 218) to support the proposal of Walford and Richardson that the *T. signata* Bed is a discrete traceable horizon.

Sample HNRC 7, a pale-grey calcareous sandy clay, was taken 0·5 m above the base of the Conglomerate Beds, about 100 m south of the main section. Whilst it is thought to be stratigraphically equivalent to sample HNRC 2, the precise correlation is obscure due to poor exposure between the localities, compounded by lateral facies changes.



TEXT-FIG. 1. Geographical location of sample localities, inset showing further details of the Hook Norton locality.



TEXT-FIG. 2. Correlation between the main section studied at Hook Norton and that of Richardson (1911).

Sample HNRC 8 was collected from a lignite-rich oolitic mud intercalated between massive bioclastic and oolitic limestones on the western side of the north cutting, about 50 m north of the tunnel entrance (SP359321; see text-fig. 1, loc. 2. It is considered to be stratigraphically higher than samples HNRC 1-7, occurring within the Hook Norton Member, and to be of Lower Bathonian age.

3. *Bruton, Somerset*. The locality at Bruton railway station (ST368847) was sampled in a temporary trench on the south side of the railway line. The sample (BRUT 1) of blue/grey silty mud containing abundant *Praexogyra acuminata* (J. Sowerby) was collected about 0·3 m below track level. Stratigraphically the sample is located within the *Acuminata* Beds, which are placed at the top of the Lower Fuller's Earth Clay. These beds have yielded ammonite faunas which underlie the *T. subcontractus* Zone and have been correlated with the upper part of the *P. progracilis* Zone of the Middle Bathonian (Torrens 1974).

PREVIOUS RESEARCH

Comparatively little has been published on the palynology of strata around the Bajocian-Bathonian boundary. The earliest papers are those of Valensi (1948, 1953), which were concerned with the Middle Jurassic microplankton from the Normandy and Poitiers regions of France. Despite the precise taxonomic investigation undertaken, scant attention was paid to stratigraphical distribution.

In 1966 W. Wetzel published a paper describing several new taxa from the *G. garantiana* Zone of Bielefeld, north-west Germany. In the same year Stover produced a short taxonomic paper describing a new species of *Nannoceratopsis* from the Lower Bathonian of Normandy. Unfortunately, little mention was made of the other microplankton elements within the assemblage. The publication of the classic Bathonian paper of Gocht (1970), whilst investigating the Lower Bathonian of some borehole cores in north-west Germany, described several new species and added a great deal to the understanding of dinoflagellate cyst ultrastructure.

Johnson and Hills (1973) published a palyno-stratigraphy of the Middle Jurassic Savik Formation from Arctic Canada. Unfortunately the assemblages round the Bajocian-Bathonian boundary were low in diversity and dominated by acritarchs and species of *Nannoceratopsis*. Van Helden (1977) also described assemblages from Arctic Canada, again dominated by the genus *Nannoceratopsis*. Fenton and Fisher (1978) give a brief description of microplankton in the Upper Bajocian-Lower Bathonian, within a broad account of Middle Jurassic (excluding the Callovian) microplankton ranges and geographical distribution in north-west Europe.

LIST OF TAXA CITED

DINOFLAGELLATE CYSTS:

A comprehensive bibliography of cited taxa is given by Lentin and Williams (1977).

Chytroeisphaeridia chytroeides (Sarjeant 1962) Downie and Sarjeant 1966; *C. dictydia* Sarjeant 1972; *C. pocockii* Sarjeant 1968; *Cleistosphaeridium polytrichum* (Valensi 1947) Davey *et al.* 1969; *Ctenidodinium combazii* Dupin 1968; *C. continuum* Gocht 1970; *C. ornatum* (Eisenack 1935) Deflandre 1938; *Dichadogonyaulax adelos* sp. nov.; *D. kettonensis* Sarjeant 1976*a*; *D. norrisii* (Pocock 1972) Sarjeant 1975; *D. sellwoodii* Sarjeant 1975; *D. stauromatos* Sarjeant 1976*a*; *Ellipsoidictyum cinctum* Klement 1960; *Gongylodinium erymnoteichos* gen. et sp. nov.; *G. hocneratum* gen. et sp. nov.; *Gonyaulacysta aldorfensis* Gocht 1970; *G. crispa* (W. Wetzel) Davey *et al.* 1969; *G. dangeardii* Sarjeant 1968; *G. eisenackii* (Deflandre 1938) Dodekova 1967; *G. filapicata* Gocht 1970; *G. jurassica* (Deflandre 1938) Norris and Sarjeant 1965; *Kalyptea glabra* (Cookson and Eisenack 1960) Wiggins 1975; *Kylindrocysta spinosa gen. et* sp. nov.; *Leptodinium pectinigerum* (Gocht 1970) stat. nov.; *L. regale* Gocht 1970; *Lithodinia callomonii* (Sarjeant 1972) Lentin and Williams 1977; *L. decapitata* (W. Wetzel 1966) Lentin and Williams 1977; *L. deflandrei* (Sarjeant 1968) Lentin and Williams 1977; *L. jurassica* Eisenack 1935; *L. valensii* (Sarjeant 1966) Lentin and Williams 1977; *Nannoceratopsis gracilis* Alberti 1961; *N. pellucida* Deflandre 1938; *N. spiculata* Stover 1966; *Pareodinia ceratophora* Deflandre 1947; *P. ceratophora* subsp. *scopeaus* (Sarjeant 1972) Lentin and Williams 1973; *Scriniodinium crystallinum* (Deflandre 1938) Klement 1960; *Tenua asymmetra* sp. nov.; *T. verrucosa* Sarjeant 1968; *Valensiella ampulla* Gocht 1970; *V. ovula* (Deflandre 1947) Eisenack 1963; *Wanaea acollaris* Dodekova 1975.

ACRITARCHS:

Caddasphaera halosa (Filatoff 1975) gen. nov. comb. nov.; *Cymatiosphaera eupeplos* (Valensi 1947) Deflandre 1954; *Micrhystridium fragile* Deflandre 1947; *M. stellatum* Deflandre 1942.

SYSTEMATIC PALYNOLOGY

Class DINOPHYCEAE Fritsch
Order PERIDINIALES Haekel
Family DICHADOGONYAULACEAE Sarjeant and Downie 1974
Genus DICHADOGONYAULAX Sarjeant 1966 emend. Sarjeant 1975

1966 *Dichadogonyaulax* Sarjeant *in* Davey *et al.*, p. 153.
1975 *Dichadogonyaulax* Sarjeant, 1966 emend. Sarjeant, p. 50.

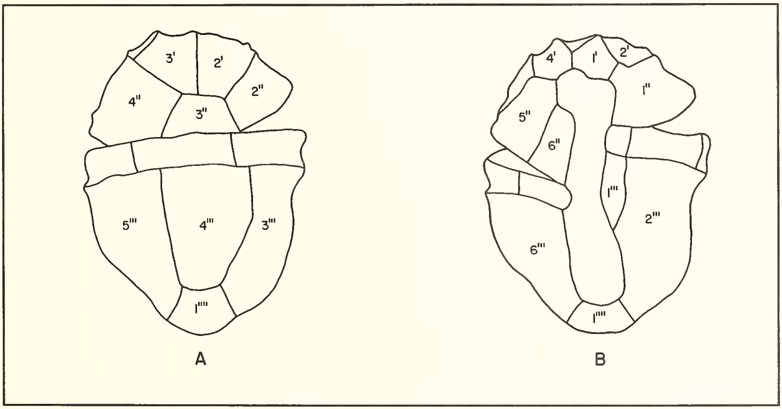
Type species. Dichadogonyaulax culmula (Norris 1965, p. 793, figs. 1, 2, 6–9) Loeblich Jr. and Loeblich III, 1968, p. 211.

Dichadogonyaulax adelos sp. nov.

Plate 14, figs. 1–4; text-fig. 3

1978 Dinoflagellate sp. A *in* Fenton and Fisher, pl. 1, fig. 7.

Diagnosis. Small proximate cyst, spheroidal to ovoidal outline, dorso-ventrally flattened. Lacking polar and median horns. Epicyst slightly smaller than hypocyst. Paracingulum relatively broad, strongly laevorotatory. Parasutures absent or indistinct, defined by simple lines, low rounded ridges, or rarely by alignment of low granules. Parasutures preferentially developed on epicyst. Paratabulation formula 4′, 6″, 6c, 6‴, 1⁗. Archaeopyle epicystal, schism occurring along the anterior margin of the paracingulum.



TEXT-FIG. 3. Camera lucida drawing of *Dichadogonyaulax adelos* sp. nov., holotype, showing paratabulation. A, dorsal view by transparency. B, ventral view. ×*c*. 1260.

Description. The cyst possesses a ?double-layered wall, up to 1 μm thick. The epicyst is slightly smaller than the hypocyst, the latter appearing to be more rigid in construction than the epicyst which is prone to break up along the parasutures. Four apical paraplates occur, paraplate 1′ occupying an anterior prolongation of the parasulcus. Paraplates 2′–4′ are polygonal, with paraplate 4′ being slightly reduced in area. Six roughly trapezoidal precingular paraplates occur, with paraplate 3″ being reduced in area. Paraplate 6″ is reduced to an elongate shape adjacent to the anterior parasulcal area.

The paracingulum is relatively broad (3–5 μm), strongly laevorotatory and offset by about twice its width. It is subdivided into six paraplates, with paraplate 1c the smallest. The undivided parasulcus is long and extends almost the whole length of the ventral surface. An expansion in width of the anterior area creates the impression of an intercalary paraplate, but no confirmative evidence could be found. The width is approximately constant on the hypocyst.

Six postcingular paraplates are identified, with paraplate 1‴ being severely reduced becoming narrow and elongate. The remainder are approximately trapezoidal in outline. The antapex is made up of a single small, subquadrate paraplate.

The surface of the cyst varies from faint to coarsely scabrate, with the occasional development of low (< 1 μm) isolated granules. The granules, when present, are often aligned in rough approximation to the parasutures. The latter are normally indistinct and may be completely absent from the hypocyst. The parasutures are best developed as very low rounded ridges (< 1 μm) or lines along which the epicyst may break up. In all the specimens observed the epicyst remained attached to the hypocyst on the ventral surface after archaeopyle development.

Dimensions. Cyst width—26(30)37 μm (18 specimens measured), length—30(35)48 μm; holotype width—37 μm, length—48 μm.

Occurrence. HNRC 1, 2.

Holotype. Plate 14, fig. 3 and text-fig. 3. *Paratypes.* Plate 14, figs. 1, 2.

Type horizon. Sample HNRC 1, base of Hook Norton Conglomerate Beds, Hook Norton, Oxfordshire, England. *P. bomfordi* Subzone, *P. parkinsoni* Zone, Upper Bajocian.

Remarks. D. adelos differs from all other species of *Dichadogonyaulax* by its small size, paratabulation, and parasutural ornament. The paratabulation is very indistinct, only being fully resolved on the holotype. Its absence on the hypocyst gives *D. adelos* a superficial resemblance to the genus *Mancodinium* Morgenroth, 1970. However, the latter differs in possessing a more complex epicystal paratabulation and a non-tabulate hypocyst.

D. adelos has also been recorded from the *H. discites* and *W. laeviuscula* zones (Lower Bajocian) of eastern England (Fenton and Fisher 1978).

Derivation of name. Adelos, Greek—obscure; with reference to the indistinct paratabulation.

EXPLANATION OF PLATE 14

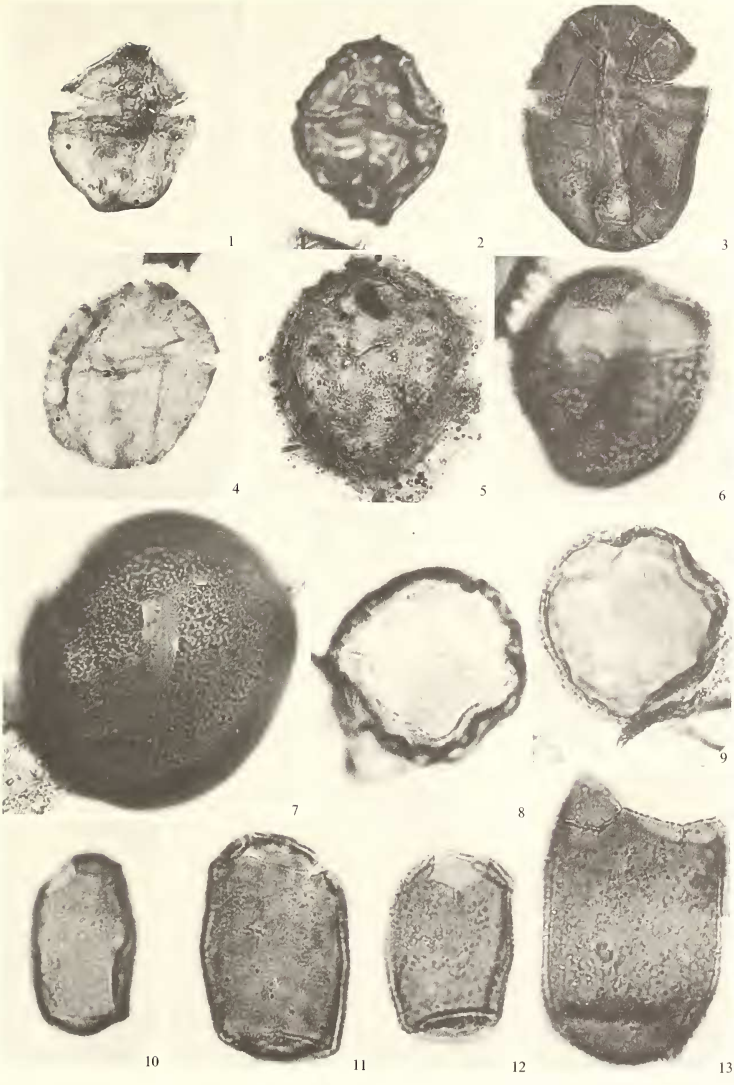
All magnifications × 1000.

Figs. 1–4. *Dichadogonyaulax adelos* sp. nov. 1, paratype, median view, HNRC 2ci (H43/4). 2, paratype, dorsal view, HNRC 2ci (V36/3). 3, holotype, ventral view, HNRC 1ci (L36/1). 4, dorsal view, HNRC 2ci (V37/4).

Fig. 5. *Caddasphaera halosa* comb. nov. HNRC 1ci (O29/4).

Figs. 6–9. *Gongylodinium erymnoteichos* gen. et sp. nov. 6, paratype, dorsal view, BB5 cii (R45/4). 7, ventral view, BB5 cii (M39/0). 8, holotype, dorsal view, HNRC 4cii (V39/4). 9, holotype, median view.

Figs. 10–13. *Kylindrocysta spinosa* gen. et sp. nov. 10, paratype, lateral view, HNRC 2ci (H43/4). 11, paratype, lateral view, HNRC 8ci (N46/0). 12, paratype, ventral view, HNRC 8ci (U46/0). 13, holotype, lateral view, BB5 ci (T50/1).



FENTON, NEVES and PIEL, Jurassic microplankton

Family GONYAULACYSTACEAE Sarjeant and Downie, 1966
Genus LEPTODINIUM Klement, 1960 emend. Sarjeant, 1969

Type species. Leptodinium subtile Klement, 1960, p. 46, pl. 6, figs. 1-4, text-figs. 23, 24.

Leptodinium pectinigerum (Gocht, 1970) comb. nov.

1970 *Leptodinium subtile* subsp. *pectinigerum* Gocht, p. 138, pl. 33, figs. 1-4, text-fig. 11.

Remarks. The species is elevated from subspecific to specific rank, since we consider that it differs sufficiently from *L. subtile*. The major differences are the presence of a blunt, often conspicuous apical horn formed by the coalescing of the parasutural crests, and the highly denticulate to spinose parasutural crests. *L. subtile* lacks an apical horn and possesses unornamented parasutural crests.

The apical horn in *L. pectinigerum* is slightly displaced towards the ventral surface, as noted by Gocht (1970); the full paratabulation formula is: 4′, 6″, ?6c, 6‴, 1p, 1⁗, 1pv, 1ps.

Several specimens were observed with very finely perforate parasutural crests, but further specimens are required before a complete reappraisal of the species can be made.

L. pectinigerum has been recorded by Fenton and Fisher (1978) from the Upper Bajocian (*G. garantiana* Zone) to Upper Bathonian of north-west and south-west Germany. It has also been recorded by one of us (J. P. G. F.) from the Lower Callovian (*M. macrocephalus* Zone) of eastern England.

Family APTEODINIACEAE Eisenack, 1961 emend. Sarjeant and Downie, 1972
Genus GONGYLODINIUM gen. nov.

Type species. Gongylodinium erymnoteichos sp. nov.

Diagnosis. Proximate, non-tabulate cyst, spheroidal to ovoidal in outline. Paracingulum and parasulcus absent or very indistinct. Archaeopyle formed by loss of two trapezoidal paraplates in a dorsal precingular position. Thickness of wall variable. Ornament varying from smooth to scabrate to granulate or spinose, evenly distributed. Polar and median horns absent.

Remarks. Gongylodinium differs from all other genera in lacking polar and median horns and possessing a two-paraplate precingular archaeopyle. The genus bears a superficial resemblance to *Bitectatodinium* Wilson, 1973, described from the Middle Pleistocene of New Zealand, but differs in possessing larger opercular paraplates and a simpler non-tectate wall structure. It also differs from *Occisucysta* Gitmez, 1970 by lacking a definable paratabulation.

Derivation of name. Gongylos, Greek—round, spherical; with reference to the cyst shape of the type species.

Gongylodinium erymnoteichos sp. nov.

Plate 14, figs. 6-9

1965 *Leiosphaeridia scrobiculata* Deflandre and Cookson, 1955 *in* Dupin, pl. 2B, fig. 2.
1970 Gen. et sp. indet. 5 *in* Gocht, p. 153, pl. 34, fig. 28, text-fig. 27.
1978 Gen. et sp. indet. 5 *in* Fenton and Fisher, pl. 1, fig. 17.

Diagnosis. Proximate, non-tabulate cyst, spheroidal to slightly ovoidal outline. Paracingulum absent; parasulcus occasionally defined by reduction or absence of ornament. Archaeopyle formed by loss of two paraplates corresponding to a dorsal precingular position relative to the parasulcus. Double-layered wall thick, densely covered with squat spines, coni, and papillae.

Description. The normally spherical cyst is prone to collapse when the opercular paraplates are lost or have fallen inside the autocoel. Short accessory archaeopyle parasutures may occur, vaguely defining apical or ?paracingular paraplates. Occasionally a protrusion occurs at the mid-point of the anterior margin of the archaeopyle representing an anterior intercalary paraplate.

The wall is 1·5–2 μm thick and appears fairly homogeneous, with a dense cover of squat, blunt, or pointed spines, coni, or papillae. 0·5–1 μm high. The ornament may be absent or reduced on the depressed elongate parasulcal area which may be the location of preferential folding.

Dimensions. Cyst diameter—44(51)57 μm (15 specimens measured); holotype diameter—46 μm.

Occurrence. BB5, HNRC 4, 6.

Holotype. Plate 14, figs. 8, 9. *Paratype.* Plate 14, fig. 6.

Type horizon. Sample HNRC 4, Hook Norton Member, 0·7 m above the base, Chipping Norton Formation, Hook Norton, Oxfordshire, England. Upper Bajocian (*P. parkinsoni* Zone) or Lower Bathonian (*Z. zigzag* Zone).

Remarks. G. erymnoteichos is characterized by its thick wall and dense ornament cover. The archaeopyle is present in all specimens observed. The earliest record of the species is by Dupin (1965), who recorded it as *Leiosphaeridia scrobiculata*, from the Bajocian–Bathonian of the Aquitaine Basin, south-west France. A single specimen was recorded by Gocht (1970) as gen. et sp. indet. 5, and accords exactly with *G. erymnoteichos*. A single larger specimen (78 μm diameter) described as gen. et sp. indet 6 in the same paper is of questionable synonymy due to its larger size, although it appears very similar in over-all morphology. Both specimens were described from the Lower Bathonian of north-west Germany. Fenton and Fisher (1978) recorded specimens as gen. et sp. indet. 5 from the *P. parkinsoni* Zone (Upper Bajocian) to *O. aspidoides* Zone (Upper Bathonian) of south-west Germany and eastern England.

Derivation of name. Erymnos, Greek—fenced; *teichos*, Greek—wall; with reference to the castellated effect imparted by the ornamentation in section view.

Gongylodinium hocneratum sp. nov.

Plate 16, fig. 2

1970 Gen. et sp. indet. 4 *in* Gocht, p. 153, pl. 34, figs. 26, 27.

Diagnosis. Proximate, non-tabulate cyst, ovoidal or rarely spheroidal in outline. Paracingulum and parasulcus absent or indistinct. Archaeopyle precingular, by loss of two equidimensional dorsal precingular paraplates. Wall thin, smooth to scabrate.

Description. The cyst is normally ovoidal, rarely becoming spheroidal. The wall is thin, 1 μm or less, and varies from smooth to scabrate. The paracingulum and parasulcus are normally absent, but may occasionally be indicated on the ventral surface by a reduction in ornament or the presence of a shallow depression. The opercular paraplates are trapezoidal in outline, and during excystment may fall inside the autocoel. A small protrusion on the anterial archeopyle margin may indicate an intercalary paraplate. The frequent absence of this plate causes a small notch to be present on the anterior margin.

Dimensions. Cyst width—52(62)78 μm (17 specimens), length—53(62)73 μm; holotype width—61 μm, length—62 μm.

Occurrence. BB5, HNRC 1.

Holotype. Plate 16, fig. 2.

Type horizon. Sample HNRC 1, base of Hook Norton Conglomerate Beds, Hook Norton, Oxfordshire, England. *P. bomfordi* Subzone, *P. parkinsoni* Zone, Upper Bajocian.

Remarks. Although only two specimens were observed in this study, sufficient material has been described previously by Gocht (1970) and observed, and measured, by one of us (J. P. G. F.) from Lower Bathonian strata of south-west Germany, to justify the erection of this new species.

The anterior margin of the archaeopyle and opercular paraplates often appears irregular and ragged as if the two paraplates have been torn from the wall. In addition the loss of these paraplates during excystment frequently causes the epicyst to be distorted.

G. hocneratum differs from *G. erymnoteichos* in lacking strong ornament, having a thinner wall, and being more ovoidal in outline. The species has been observed by one of us (J. P. G. F.) in strata of Upper Bajocian (*G. garantiana* and *P. parkinsoni* zones) and Lower Bathonian (*Z. zigzag* Zone) age in north-west and south-west Germany. To date it has not been observed outside strata assigned to these three ammonite zones.

Derivation of name. Hocneratum, Anglo-Saxon name for the village of Hook Norton, first cited in A.D. 917.

Family CANNINGIACEAE Sarjeant and Downie, 1966 emend. Sarjeant and Downie, 1974
Genus TENUA Eisenack, 1958 emend. Sarjeant, 1968

1958 *Tenua* Eisenack, p. 410.
1968 *Tenua* Eisenack, 1958 emend. Sarjeant, p. 230.

Type species. Tenua hystrix Eisenack, 1958, p. 410, pl. 23, figs. 1–4, text-fig. 10.

Tenua asymmetra sp. nov.

Plate 16, figs. 1, 3, 5

Diagnosis. Proximate, non-tabulate cyst, rounded to ovoidal outline. Wall thin, ornamented with rugulae, granules, spines, baculae, and briefly bifurcate processes concentrated at the antapical pole, becoming reduced or absent towards the apex. Paracingulum and parasulcus absent or indistinct, defined by reduction or absence of ornament. Archaeopyle apical in development with accessory parasutures defining six precingular paraplates.

Description. The outline of the cyst is variable, as the thin wall ($< 0{\cdot}5$ μm) is prone to breakage along the accessory archaeopyle parasutures. This feature exaggerates the width and facilitates easy folding of the cyst.

At the antapical pole the ornament consists of irregularly distributed rugulae, granules, blunt or pointed spines, baculae, and briefly bifurcate processes, all under 2 μm in height. The surface is coarsely scabrate, becoming faintly scabrate or occasionally smooth anterior to the coarsely ornamented antapex. The diverse ornamentation is also reduced in size and density anterior to the antapical pole. When the ornament is totally absent, often due to corrosion, the autophragm takes on an infra-vermiculate appearance. When present, the paracingulum varies between 3 and 6 μm in width.

Dimensions. Cyst width—60(74)94 μm (18 specimens measured), length—57(68)80 μm; holotype width—60 μm, length—58 μm.

Occurrence. BB5, HNRC 1, 4, 5, 8.

Holotype. Plate 16, fig. 3. *Paratype.* Plate 16, figs. 1, 5.

Type horizon. Sample BB5, *Truellei* Bed, Burton Bradstock, Dorset, England. *S. truellei* Subzone, *P. parkinsoni* Zone, Upper Bajocian.

Remarks. T. asymmetra differs from all other species of *Tenua* by the possession of asymmetrically developed ornament of great diversity. The cyst width is very approximate due to the tendency of specimens to break up along precingular parasutures, giving exaggerated dimensions.

EXPLANATION OF PLATE 15

SEM Magnifications. Fig. 1 ×3000; figs. 2, 4 ×*c*. 4000; figs. 5, 6 ×*c*. 2000. All specimens fron HNRC 2.

Figs. 1, 3. *Lithodinia valensii* (Sarjeant 1966) Lentin and Williams 1977. 1, detail of parasutural crest. 3, same specimen, detail of ventral surface.

Figs. 2, 4–6. *Kylindrocysta spinosa* gen. et sp. nov. 2, detail of closely adpressed endo- and periphragm. 4, detail of fibrous, spinose periphragm. 5, same specimen as fig. 2, detail of ?dorsal surface. 6, same specimen as fig. 4, detail of ?ventral/lateral surface, oblique view.

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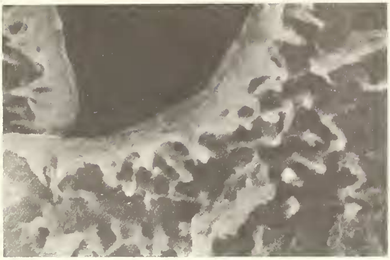

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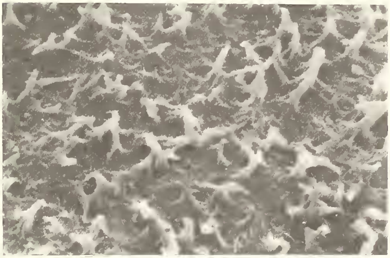

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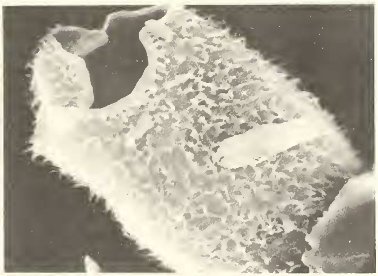

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FENTON, NEVES and PIEL, Jurassic microplankton

The species bears a close resemblance to *Cyclonephelium* Deflandre and Cookson 1955 emend. Ioannides *et al.*, 1976. *T. asymmetra* differs, however, in lacking polar horns or protuberances and ornament restricted to a circumferential zone. However, the close similarity with *Cyclonephelium* makes *T. asymmetra* possibly related to the former genus.

When the ornament is developed at its best the species appears similar to *Chytroeisphaeridia pocockii* Sarjeant, 1968, although it differs by being larger and possessing an antapical polar concentration of ornament.

Derivation of name. Asymmetros, Greek—without symmetry; with reference to the distribution of ornament.

Family UNCERTAIN
Genus KYLINDROCYSTA gen. nov.

Diagnosis. Proximate cyst, cylindrical, strongly elongate to subquadrate in outline. Paratabulation absent or indistinct. Paracingulum and parasulcus apparently absent. Apex flattened or convex, composed of five paraplates, bulk of cyst composed of five elongate paraplates; with a flat to convex pentagonal antapical paraplate. Cyst wall complex, consisting of thin endophragm and spongy, fibrous periphragm, closely adpressed. Cyst surface spinose to granulose. Paratabulation formula 5′, ?5″, ?5‴, 1⁗. Archaeopyle formed by loss of two or more apical paraplates.

Type species. Kylindrocysta spinosa sp. nov.

Remarks. Kylindrocysta differs from all other genera by its shape, paratabulation formula, and type of archaeopyle. The closest comparable genus is *Pyxidiella* Cookson and Eisenack, 1958, but the latter differs in possessing a distinct intercalary archaeopyle and lacks a definable paratabulation.

Comparodinium Morbey, 1975 may possess a similar type of archaeopyle, in that it involves partial or total loss of the apical paraplates; it differs, however, in the possession of a distinct paracingulum and chorate structure to the cyst.

A similarity may be observed between *Kylindocysta* and *Pareodinia* Deflandre, 1947 emend. Wiggins, 1975 when partial loss of the apical paraplate series has occurred. *Kylindrocysta*, however, differs from *Pareodinia* in possessing a more angular shape, simpler paratabulation, more complex wall structure, and lacking an apical horn.

Kylindrocysta spinosa sp. nov.

Plate 14, figs. 10–13; Plate 15, figs. 2, 4–6

1970 *Pyxidiella* sp. *in* Gocht, p. 156, pl. 35, figs. 11, 12, text-figs. 28–30.

Diagnosis. Proximate cyst, cylindrical, elongate or subquadrate in outline. Cyst wall complex, consisting of thin endophragm and thicker fibrous periphragm, the latter bears a spinose ornament of medium to dense distribution. The apex consists of five apical paraplates, two ?dorsally inclined, subquadrate paraplates, and three smaller paraplates on the ?ventral surface. Archaeopyle formed by the loss of the two former paraplates or combination of all five paraplates. Remainder of cyst composed of five elongate to subquadrate paraplates and a single antapical paraplate. Paratabulation formula 5′, ?5″, ?5‴, 1⁗.

Description. Cyst normally elongate, cylindrical in shape, occasionally becoming more subquadrate in outline, due to the reduction in the length of the five elongate paraplates, which constitute the bulk of the cyst. The sides are straight to convex, never concave. The double-layered wall consists of a smooth, thin endophragm and a spongy, fibrous periphragm, the combined thickness varying between 1 and 2 μm. The periphragm appears fibrous with the individual fibres coalescing to form blunt or pointed, rarely capitate, spines, 0·5–2 μm high. The spines are medium to densely distributed over the entire cyst surface.

The apex consists of five paraplates. Two large subquadrate paraplates occur inclined towards the assumed dorsal surface and these are normally lost first in archaeopyle formation, but may remain attached to a diamond-shaped paraplate on the assumed ventral surface. Either side of this latter paraplate is one smaller trapezoidal to subquadrate paraplate.

Five long paraplates make up the bulk of the cyst, occasionally defined by accessory archaeopyle parasutures extending posteriorly from the apex or anteriorly from the antapex (when the antapical paraplate is displaced or lost).

Dimensions. Cyst width—22(28)33 μm, length—31(45)56 μm; holotype width—33 μm, length—54 μm (31 specimens measured).

Occurrence. BB5, HNRC 1–8.

Holotype. Plate 14, fig. 13. *Paratypes*. Plate 14, figs. 10–12.

Type horizon. Sample BB5, *Truellei* Bed, Burton Bradstock, Dorset, England. *S. truellei* Subzone, *P. parkinsoni* Zone, Upper Bajocian.

Remarks. The double-layered nature of the wall is only visible using SEM techniques, the wall appearing single layered under the light microscope. The parasutures are frequently observed best using transmitted light microscopy, often being unobserved with SEM techniques, possibly reflecting the fact that the parasutures are only developed on the thin endophragm.

The wall thickness of the holotype (Pl. 14, fig. 13) appears to be thinner than that of the paratypes, but this is due to slight corrosion of the fibrous periphragm. The specimen was selected to display the apical paraplate configuration of the cyst.

The nomenclature of the apical paraplates is debatable due to the lack of an obvious parasulcal area to use as a reference point. However, the diamond shaped paraplate to which the two largest apical paraplates are often attached is taken to lie upon the ventral surface and may correspond to a paraplate 1′ position. We favour the view that the two adjacent paraplates are probably additional apical but could be intercalary paraplates.

The paratabulation formula observed in this study is identical to that proposed by Gocht (1970, text-fig. 30).

K. spinosa appears to have a restricted stratigraphical range, being limited to the *P. parkinsoni* and *Z. zigzig* zones, having been previously recorded from the Lower Bathonian of north-west Germany (Gocht 1970) and the *P. parkinsoni–Z. zigzag* zones of north-west Europe (Fenton and Fisher 1978).

Derivation of name. *Spinosus*, Latin—thorny; with reference to the spinose ornament.

Dinoflagellate type 1

Plate 16, fig. 6

Description. Proximate, ?non-tabulate cyst, biconical in outline. Epi- and hypocyst of similar proportions. Cyst wall single layered (autophragm) thin, under 0·5 μm thick, scabrate. The conical epicyst has concave sides and is surmounted by a fairly broad, slightly rounded, hollow apical horn. Folds in the autophragm may correspond to the parasutures between the apical and precingular paraplate series. A large precingular archaeopyle is developed by the loss of one large elongate paraplate (3″). Parasulcus absent, paracingulum possibly defined by parallel folds, about 4 μm wide.

The hypocyst is extended into a distally closed, well-rounded antapical extension of the autocoel, with two folds possibly defining postcingular paraplates on the dorsal surface.

Dimensions. Cyst width—69 μm (single specimen only), length—110 μm.

Occurrence. BB5.

Remarks. Unfortunately only one well-preserved specimen of this highly distinctive cyst was observed, differing from all known genera by its shape, lack of paratabulation, cyst structure, and presence of a precingular archaeopyle. The specimen bears a superficial resemblance in outline to the genus *Tubotuberella* Vozzhennikova, 1967. The latter differs, however, in the possession of a distinct endophragm and an opisthopyle at the antapex.

Numerous specimens have been observed by one of us (R. N.) from strata assigned to a post-Aalenian–pre-Lower Kimmeridgian age from the northern North Sea Basin.

Dinoflagellate type 2

Plate 16, fig. 4

Description. Proximate, non-tabulate cyst, originally spherical, distorted due to folding. Cyst wall varying between 0·5 and 1 μm in thickness. Ornament ranges from coarsely scabrate to coarsely granular (< 1 μm high). Paracingulum absent, parasulcus possibly defined by reduction of ornament. Archaeopyle formed by the loss of three paraplates, equating with a precingular position relative to the parasulcus.

Dimensions. Cyst diameter—52–60 μm (2 specimens only).

Occurrence. HNCR 8.

Remarks. These specimens bear some resemblance to *Gongylodinium erymnoteichos* in over-all shape and construction, but differ in having smaller, less distinctive ornament and possessing a three-paraplate precingular archaeopyle. The latter feature is considered to be of sufficient significance as to preclude emplacement within *Gongylodinium*, which is restricted to cysts with a two-paraplate precingular archaeopyle.

Several specimens bearing a close resemblance to Dinoflagellate type 2 have been observed by one of us (J. P. G. F.) from the Middle-Upper Bathonian of eastern England.

Group ACRITARCHA Evitt, 1963
Subgroup SPHAEROMORPHITAE Downie, Evitt, and Sarjeant, 1963
Genus CADDASPHAERA gen. nov.

Diagnosis. Body hollow, spherical, wall thin. Surface smooth to coarsely granulate. Body surrounded by an irregular kalyptra. Excystment via a pylome, when observed.

Type species. Caddasphaera (ex *Kalyptea*) *halosa* (Filatoff, 1975) comb. nov. *in* Filatoff 1975, p. 91, pl. 29, figs. 10, 11.

Remarks. The genus is erected for simple spherical bodies with a variable ornament of acritarchous affinities, enveloped within an irregular kalyptra.

Derivation of name. Cadda, from the Cadda Formation; type locality of the type species. *Sphaera*, with reference to the body shape.

Caddasphaera halosa (Filatoff 1975) comb. nov.

Plate 14, fig. 5

1975 *Kalyptea halosa* Filatoff, p. 91; pl. 29, figs. 10, 11.

Holotype. Filatoff 1975, pl. 29, fig. 10.

Type locality. Dongara Borehole No. 5, 609·6 m, Cadda Formation, Western Australia, Lower Bajocian.

EXPLANATION OF PLATE 16

All magnifications ×1000, except fig. 6 ×750.

Figs. 1, 3, 5. *Tenua asymmetra* sp. nov. 1, paratype, median view, BB5 ciii, (P40/1). 3, holotype, ventral view, BB5 cii (O58/1). 5, paratype, dorsal view, BB5 cii (G63/3).

Fig. 2. *Gongylodinium hocneratum* gen. et sp. nov. Holotype dorsal view showing archaeopyle and opercula paraplates inside autocoel, HNRC lci (N40/4).

Fig. 4. Dinoflagellate type 2. Dorsal view showing incipient loss of three precingular paraplates, HNRC 8ci (U40/0).

Fig. 6. Dinoflagellate type 1. Dorsal view showing archaeopyle, BB5 cii (J67/0).

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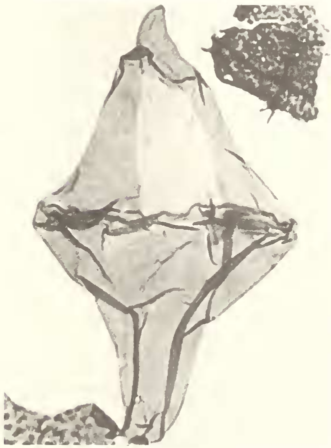

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FENTON, NEVES and PIEL, Jurassic microplankton

Diagnosis. See Filatoff 1975, p. 91.

Remarks. Filatoff inappropriately placed this distinctive species in the dinoflagellate genus *Kalyptea* Cookson and Eisenack, 1960 emend. Wiggins, 1975, a genus possessing an intercalary archaeopyle and an apical horn ± an antapical horn. This species possesses neither an archaeopyle nor polar horns and is therefore more akin to the acritarchs. The enveloping kalyptra varies greatly in width, but it is always present around the body.

C. halosa (Filatoff, 1975) has been recorded from the Upper Liassic to Albian strata of eastern England (J. P. G. F. pers. obs.).

PALAEOGEOGRAPHY AND PALYNOSTRATIGRAPHY

The assemblages recorded are important for two main reasons. Firstly they offer conclusive microfloral evidence for the absence of Scissum Beds/Northampton Sand in the southern cutting at Hook Norton and thus support the observations of Walford (1883) and Horton (1977). Secondly, they are the first detailed assemblages to be recorded from Upper Bajocian and Lower to Middle Bathonian strata.

The absence of Aalenian strata variously assigned to the Scissum Beds or Northampton Sand is of palaeogeographical interest. Observations of microplankton assemblages from the Scissum Beds and Northampton Sand in Gloucestershire and Northamptonshire respectively, indicate that only nine of the thirty-four species encountered in samples HNRC 1–3, 7 extend into Aalenian strata (J. P. G. F. pers. obs.). The majority of the remaining twenty-five species make their first appearance in the Upper Bajocian. Assemblages recovered from the Scissum Beds and Northampton Sand are very similar to those recorded by Gocht (1964) from south-west Germany, and by Fenton and Fisher (1978) from north-west Europe. Therefore no doubt can be placed upon the Upper Bajocian age assigned to samples HNRC 1–3, 7.

Arkell (1933, p. 210) drew the Scissum Line extending approximately 50 km in a south-west/north-east direction through north Oxfordshire, into east Northamptonshire. To the south-east of the Scissum Line the Scissum Beds and the laterally equivalent Northampton Sand are overstepped by Upper Bajocian or younger strata. Arkell originally drew a more or less straight Scissum Line passing south of Swerford, which lies approximately 1 km to the south-east of Hook Norton south cutting. Horton (1977), on the basis of detailed field mapping and borehole evidence partially revises the Scissum Line (renamed Limit of Northampton Sand and Limit of Scissum Beds pockets) by drawing it in the vicinity of south cutting at Hook Norton (Horton 1977, fig. 4). Approximately 2·1 m of Aalenian strata (Scissum Beds) are overstepped by the Upper Bajocian within about 0·5 km between the north and south cuttings at Hook Norton.

In an area with relatively rare macrofaunal evidence for age determination, the presence of richly palyniferous horizons may be of use in determining a more precise stratigraphy and subsequently a more correct palaeogeography. In Oxfordshire and Northamptonshire, where a major stratigraphical hiatus separates Upper Bajocian and younger strata from Aalenian or older strata, the study of microplankton assemblages may be a readily applicable tool as differentiation between Aalenian and Upper Bajocian or younger assemblages is normally very easy.

From the stratigraphical aspect the assemblages appear fairly homogeneous, with key species being few in number and rare components of the assemblages (Table 1). The close similarity between Upper Bajocian and Lower Bathonian assemblages has been noted by Fenton and Fisher (1978). All the samples are rich in cysts with epicystal archaeopyles. The Bruton and Burton Bradstock samples have *Ctenidodinium* as the most abundant genus, whilst the Hook Norton samples are dominated by species of *Lithodinia* and *Dichadogonyaulax*, especially *D. stauromatos*.

Of the species recorded, *G. hocneratum*, *Nannoceratopsis gracilis*, *L. valensii*, and *Kylindrocysta spinosa* do not occur in strata younger than Lower Bathonian, whilst *D. adelos* and *Gonyaulacysta crispa* do not appear, at present, to extend stratigraphically higher than the Upper Bajocian (*P. parkinsoni* Zone). The remaining species which are here restricted to the Upper Bajocian: *D. norrisii*, *G.* cf. *dangeardii*, *Valensiella ampulla*, and *Cleistosphaeridium polytrichum* all range into

TABLE 1. Stratigraphical distribution of microplankton. O is recorded occurrence during present investigation; -O- known ranging into older and/or younger strata.

	BB 5	HNRC 1	HNRC 2	HNRC 7	HNRC 3	HNRC 4	HNRC 5	HNRC 6	HNRC 8	BRUT 1
Dinoflagellate type 1	O									
Dichadogonyaulax norrisii	-O-									
Gonyaulacysta cf. dangeardii	O-									
Cleistosphaeridium polytrichum	O-									
Gongylodinium hocneratum	-O	O								
Nannoceratopsis gracilis	-O	O								
Leptodinium pectinigerum	-O	O-			O		O-			
Lithodinia valensii	-O	O	O		O	O	O	O		
L. jurassica	O	O	O	O	O	O	O	O-		
Dichadogonyaulax sellwoodii	O		O		O	O	O	O	O-	
D. stauromatos	O	O	O	O	O	O	O		O-	
Ellipsoidictyum cinctum	O		O						O-	
Tenua asymmetra	O	O				O	O		O	
Nannoceratopsis pellucida	O							O	O-	
Gongylodinium erymnoteichos	-O					O			O-	
Leptodinium regale	-O	O	O			O			O-	
Lithodinia cf. deflandrei	-O	O	O		O	O	O	O	O-	
Kylindrocysta spinosa	O	O	O		O	O	O	O	O	
Chytroeisphaeridia pocockii	-O		O	O				O	O-	
Ctenidodinium combazii	O									O-
C. continuum	O		O		O					O-
C. ornatum	-O								O	O-
Gonyaulacysta aldorfensis	-O	O	O			O			O	O-
G. filapicata	-O	O		O			O			O-
Nannoceratopsis spiculata	-O		O			O	O	O	O	O-
Micrhystridium stellatum	-O		O		O	O	O	O	O	O-
M. fragile	-O	O	O			O	O		O	O-
Wanaea acollaris	O	O							O	O-
Pareodinia ceratophora	-O	O	O	O	O	O	O	O	O	O-
Dichadogonyaulax kettonensis	O	O	O		O	O	O	O	O	O-
Chytroeisphaeridia chytroeides	-O	O	O	O	O	O	O	O	O	O-
Valensiella ovula	-O	O	O		O	O	O	O	O	O-
Gonyaulacysta crispa		-O								
Valensiella ampulla		O	O-							
Dichadogonyaulax adelos		-O	O							
Caddasphaera halosa		-O	O	O	O	O	O	O-		
Chytroeisphaeridia dictydia		O							O-	
Kalyptea glabra		-O	O-							
Lithodinia decapitata/callomonii		O	O	O	O		O		O	O-
Gonyaulacysta eisenackii			O			O	O			O-
Scriniodinium cf. crystallinum					O-					
P. ceratophora subsp. scopaeus					O	O-				
Cymatiosphaera eupeplos						-O-				
Gonyaulacysta jurassica						O-				
Tenua verrucosa						O			O	O-
Dinoflagellate type 2									O-	
	TRUELLEI BED	H. NORTON CONG. BEDS				H. NORTON MEMBER				ACUMINATA BED
	BAJOCIAN					BATHONIAN				

younger strata in other geographical areas. The stratigraphical usefulness of Dinoflagellate type 1 and Dinoflagellate type 2 has yet to be evaluated.

For the purpose of defining the Bajocian–Bathonian boundary five species are thought to be of use. *D. adelos* and *G. crispa* are not known above the Upper Bajocian, whilst *G. jurassica*, *Scriniodinium* cf. *crystallinum* and *Tenua verrucosa* all appear, almost coincidentally, with the base of the Chipping Norton Formation. The effect of facies control upon the cyst assemblage is unknown, but little change occurs within the remainder of the assemblages spanning the formational boundary. Therefore, using palynological criteria to define the Bajocian–Bathonian boundary it appears that it may be drawn between samples HNRC 3 and 4, which equates approximately with the base of the Chipping Norton Formation. This is slightly lower than the extrapolated boundary from Chipping Norton Workhouse Quarry, assuming the *T. signata* Bed to be a synchronous deposit, although Horton (1977) states that no evidence can be found to support this.

The provincialism of dinoflagellate cysts, noted by Fenton and Fisher (1978) in the Upper Bathonian, may have been in existence at this earlier period. In their discussion they identify a Tethyan realm (southern Europe) and a Boreal realm (Greenland and Arctic Canada). The former has microplankton assemblages dominated by species of *Ctenidodinium*, especially *C. combazii*, whilst the latter is dominated by proximate cysts and is, in general, lacking cysts with epicystal archaeopyles. Eastern England is shown to possess a Boreal-type assemblage with the addition of species of *Dichadogonyaulax*. Oxfordshire is shown to be an area of mixing of this assemblage type with the *Ctenidodinium* dominated Tethyan assemblage.

Reference to Table 1 shows that *C. combazii*, although recorded at the top and bottom of the composite section studied, is only present in the more southern localities, at Burton Bradstock and Bruton. When species of *Ctenidodinium* (*C. continuum*, *C. ornatum*) are present in the Hook Norton assemblages they are heavily outnumbered by specimens attributable to various species of *Dichadogonyaulax* (*D. kettonensis*, *D. adelos*, *D. stauromatos*, and *D. sellwoodii*), which is the dominant genus in assemblages HNRC 1–8. The Upper Bajocian assemblage from Burton Bradstock (Dorset) contains approximately equal proportions of species of *Dichadogonyaulax* and *Ctenidodinium*, whereas the Upper Bathonian of Dorset contains a marked paucity of *Dichadogonyaulax* (Fenton and Fisher 1978). Assemblages from the Upper Bajocian (*P. parkinsoni* Zone) and Lower Bathonian (*Z. zigzag* Zone) of south-west Germany, and south-west and northern France contain a predominance of *Ctenidodinium* species, especially *C. combazii*, suggesting Tethyan realm affinities. The assemblage from Burton Bradstock exhibits a mixed Boreal/Tethyan microplankton content similar to those obtained from Oxfordshire in the Upper Bathonian. To explain this, assuming that facies control upon the cyst assemblages is negligible, it is suggested that waters containing abundant *Ctenidodinium* cyst producing motile dinoflagellate thecae transgressed northwards during the Lower Bathonian–Lower Callovian, moving the intermediary zone of mixing of assemblage types from Dorset in the Upper Bajocian to Oxfordshire and eastern England in the Upper Bathonian, eventually reaching the Moray Firth area (north-east Scotland) during the Lower Callovian (L. A. Riley pers. comm.).

CONCLUSIONS

Study of large assemblages of microplankton from samples spanning the Bajocian–Bathonian boundary show few diagnostic changes. It is thought that the youngest occurrence of *D. adelos* and *G. crispa* associated with the first occurrences of *G. jurassica*, *S.* cf. *crystallinum* and *T. verrucosa* may indicate the proximity of the Bajocian–Bathonian boundary.

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